RESEARCH IN MECHANICAL FARM EQUIPMENT, 1928*

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The development of effective investigations in farm machinery, farm power, and related subjects during the year speaks well for the efforts of the Advisory Council on Research in Mechanical Farm Equipment. The growth of well-directed inquiry into these subjects is reflected in the fact that 17 Purnell studies of mechanical farm equipment were active during the year at 11 agricultural experiment stations. The Louisiana Station led with 3, the South Dakota, Montana, and Pennsylvania Stations had 2 each, and the Georgia, Massachusetts, West Virginia, Alabama, Nebraska, North Dakota, and California Stations had 1 each. The subjects dealt with were seeding machinery, fertilizer distributors, combines, traction machinery, tillage machinery, corn harvesting machinery, artificial hay curing equipment, cane milling machinery, the development of power and labor-saving machinery for growing corn, soy beans, garden vegetables, potatoes and hay, soil dynamics as related to tillage implement design, and bearing wear in tractor engines as related to lubrication. In addition the Alabama Station continued the Adams fund study of the influence of soil dynamics on traction.

A record of the total number of mechanical farm equipment projects active at the agricultural experiment stations during the year is not available. However, during the previous year the total number active was 85, so far as can be determined. From the results of official visits to the stations during the year there is evidence that, in several cases at least, the total number of mechanical equipment projects was materially increased, and in several cases the work was strengthened by the revision of existing projects along more sound lines or by the substitution of new or stronger projects for old ones. Several foreign research agencies seemed also to have caught the spirit and undertook rather profound studies of mechanical farm equipment.

It is impossible to completely review the progress of all the work done in the subject in this country and abroad during the year. However, attention is drawn in the following to a few of the outstanding results to indicate the progressive trend.

TRACTION MACHINERY

Considerable progress was reported during the year in the development of traction machinery with particular reference to the improvement of specific features to better adapt available traction devices to the difficult and severe conditions imposed by agricultural operations. The tractor tests conducted at the Nebraska Experiment Station seemed to have deviated somewhat from the usual practice of routine testing in order to establish certain fundamental principles. In this connection several improvements in tractors have been brought to light. For example, the fuel consumption records indicated a decided improvement in the past

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few years. In 1927 the average figures were 9.8 horsepower hours per gallon of fuel, or 0.68 pounds per horsepower hour. The power available for a given weight of tractor has been materially increased, varying from a static weight of 356 pounds per drawbar horsepower in 1920 to 233 pounds per drawbar horsepower in 1927. Drawbar efficiency has increased from an average of 69.2 per cent in 1920 to 74.9 per cent in 1927. The rate of travel has increased from an average of 2.49 miles per hour in 1920 to 3.25 miles per hour in 1927. At the beginning of the tractor testing season of 1928 a new procedure was incorporated in the method of testing tractors which involved the use of one carburetor setting for all tests, whereas formerly the carburetor was adjusted for each test. This change makes the test results more nearly correspond to results obtained in the field by the average operator and introduces uniformity into the testing. The results indicate the possibilities and advantages of a carburetor designed to operate economically over a wide range of loads without changing its adjustment. They also indicate that the manifolding should be verified by actual tests before final adoption since the beneficial results of a good carburetor may be almost lost if used in conjunction with a poor manifold.

In tests of tractor wheel equipment the Pennsylvania Experiment Station found that rubber tired wheels without chains provided sufficient traction for general field work other than plowing only under the most favorable conditions. A little moisture on the surface caused the wheels to spin. However, a tractor equipped with rubber tired drivewheels and metal front wheels could be driven at four miles per hour over rocky farm roads with perfect comfort to the operator. Rubber tired front wheels made steering difficult. The ground appeared to be packed more by rubber tired wheels than by any metal wheels. Spade lugs on an 11-inch rim gave the best traction of all wheels tested, both on plowed ground and on sod. Angle lugs on a 6-inch rim gave practically the same traction as the open wheel with cone lugs.

In a continuation of the study of the fundamental factors influencing the traction of wheel tractors the Alabama Experiment Station established correlations between laboratory data and field results with actual tractors. In plaster cast studies of force distribution in soil a comparatively close check was obtained between calculated and actual distortion. The weight on the wheel and the depth of the lug are functions of the direction and amount of soil distortion. Shear in the soil takes place perpendicularly to the resultant of lug and rim displacement. By taking advantage of the arch action of the soil the lines of shear can be given greater distortion through the soil, resulting in a greater drawbar pull by the tractor.

The California Experiment Station found that a properly selected drawbar spring can give satisfactory overload protection at low and medium tractor speeds if the implement is designed to withstand safely a drawbar pull of 1.5 to 2 times the maximum tractive ability of the tractor. At higher speeds a spring is not practical to replace the breakpin, but springs may be used to reduce stresses resulting from increased loads or speed, and thus reduce the frequency of breakpin replacements. The effectiveness of a spring strong enough not to be completely compressed in preventing increase in the drawbar pull varies as the value of the speed of the tractor times the square root of the product of its weight and the load deformation ratio of the spring. Studies of spring-held overload release hitches showed that such hitches should have uniformity of pull for release at given adjustments and this pull should be proportional to the adjustment.

The above results are typical of efforts being made to meet the conditions and requirements for traction in agricultural operations. Evidently there is much need for further development of available traction machinery along specific lines. A knowledge of the requirements to be met in each operation is obviously of considerable importance, and the necessity for a coordination of effort with the subject-matter specialists in agriculture seems without question.

INTERNAL-COMBUSTION ENGINE FUELS

Considerable work was reported during the year on the development of fuels for use in internal-combustion engines which for the most part was done by agencies other than agricultural engineering. Attention was drawn in a recent report by Colonel O. B. Zimmerman* to the importance of this subject in connection with the development of agricultural traction machinery along both efficient and economical lines.

With reference to the use of alcohol as an internal-combustion engine fuel the California Experiment Station reported the finding that most farm gas engines on the present American market can be operated with mixtures of gasoline or kerosene and alcohol without structural changes. Mixtures of alcohol with either gasoline or kerosene were found to have less tendency to deposit carbon than either kerosene or gasoline alone, and also less tendency to dilute the oil. Smoother operation was also secured. The Australian Council of Scientific and Industrial Research, however, reported the finding that the necessary raw materials are, in general, too valuable as food stuffs to permit their distillation into power alcohol. It appears, however, that in certain parts of Australia raw materials can be produced at such a cost as will enable any alcohol distilled from them to compete locally with gasoline.

Considerable work was done by various agencies on methods of knock suppression in fuels. The University of Iowa, for example, demonstrated the value of nickel colloids in this connection. The University of Birmingham in England found that certain pure hydro-carbons have appreciable knock-suppressing qualities. The University of Illinois reported that a compound to have suitable antiknock properties must be an inhibitor of gas-phase oxidation and an accelerator of liquid phase oxidation. Studies conducted at Yale University indicated that the carbon removal saving resulting from the use of a fixed doped fuel is highest for the lowest compression ratio and vice versa. The fuel saving has a definite relationship with compression ratio and is directly proportional to the cost of fuel for any compression ratio. It appears that the economy of the use of doped fuel at a compression ratio of 5 to 1 depends entirely upon carbon removal savings, a low cost of carbon removal and long milage before removing carbon making the use of doped fuel uneconomical, and vice versa. The University of Toronto drew the further conclusion that there is no economic advantage

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in buying antiknock fuels at a three cent premium if an engine having a compression ratio of 5.5 to 1 can be operated satisfactorily on ordinary gasoline. It was also found that there is no gain in power or economy by using special lubricants in fuels.

The above typical results suggest that much is yet to be learned regarding fuels for internal-combustion engines. Since power for traction is one of the large items in the cost of agricultural production, it would seem worth while for agricultural engineers to give some consideration to the fuel development problem, with particular reference to the requirements of specific power operations.

TILLAGE MACHINERY

Several developments took place during the year with reference to tillage and tillage machinery. The Alabama Station, in continuing its studies of the influence of soil dynamics on the design of tillage machinery, found that the adhesive properties of tillage implement metal can be varied by various heat treatments. In fact, rapid cooling of the metal from the nonrigid state in mercury resulted in the lowest adhesion of soil to the metal surface. The importance of these findings from the standpoint of the power requirements of tillage can not be overestimated.

A private agency in reporting the results of a large number of tillage experiments emphasized the importance of the physical aspects of soil organic matter in this connection. A constantly increasing content of organic matter in the soil, regardless of its nature, was found to result in a corresponding decrease in the amount of power required to pull a plow whether the ground was dry and hard, or in ideal condition for plowing. A nonscouring condition in acid soil could be cured by the correction of the acidity and by increasing the organic matter content regardless of the size or shape of the plow. In this connection the New Jersey Experiment Station reported that the plowing draft of a soil tends to increase as the crop yield increases, due to the heavier root development and the greater resistance to the plow by soils of higher fertility. It was found, however, that the draft required to plow limed soils is less than that for nonlimed soils in spite of the normally higher yields following the liming of soils and the consequent increase in root development. The Arkansas Experiment Station concluded from 500 plow draft tests that the draft per unit area of furrow section is inversely proportional to the depth of cut and to the width of plow bottom.

Some progress was made at both the Iowa and Indiana Experiment Stations in the development of rotary tillage devices. At the former station a measure of success was secured with a machine in which the moldboard of a standard plow is replaced by a revolving pulverizer head having blades which engage the furrow slice and beat and mix the soil. The reduction of drawbar horsepower under that required for a plow is sufficient to furnish a large part of the power needed to drive the pulverizer.

The above typical findings relating to the development of tillage machinery suggest the importance of cooperation with agronomists and soil technologists in determining the requirements of specific soils for tillage

as a basis for the development of tillage implement parts.

HARVESTING AND THRESHING MACHINERY

It is being recognized that the development of satisfactory and economical methods and equipment for the harvesting of crops calls for the coordination of the forces of agronomy and agricultural engineering in studies of conditions and requirements for harvesting, with the idea of adapting available machines or of developing the principles of new ones which will perform this operation satisfactorily. This is particularly true in the harvesting and threshing of grain, and considerable work was done during the year with the combining procedure for the purpose of showing in what specific details available combine machinery falls short of satisfactorily, as well as economically, performing the necessary operations.

The North Dakota Experiment Station found, for example, that any good combine when properly adjusted will thresh all the grain from dry wheat heads. When the grain contains green weeds the power requirements for combining were increased since the weeds clogged the elevators and screens and interfered with the threshing and separator operations. A more serious drawback was the moisture added to the otherwise dry grain either by green weed seeds, particles of green weeds, or juices mashed from green weeds as they passed through the combine.

The Pennsylvania Experiment Station found that the combine method effected a considerable saving in the cost of harvesting wheat and oats when the straw was left on the field, but when the straw was removed it cost more to harvest by this method than by binding and threshing. Studies of the effect of weather conditions on the moisture content of standing grain showed that no definite hour in the morning for starting the combine is indicated since it appears to depend entirely upon weather conditions.

The Canada Experimental Farms reported the introduction of the swather attachment in the use of the combine. In this connection the Minnesota Experiment Station found that the use of the windrower is almost indispensable when combining a weedy field. The Missouri Experiment Station found that the windrowing system reduces the trouble due to high moisture content and tends to lower threshing losses in weedy grain. The California Experiment Station reported progress in the development of methods and equipment for the efficient and economical handling of grain in bulk, especially wheat, barley, and rice. The bulk storage of rice without heating was successful. The Michigan Station found that beans can be harvested and threshed with regular combine equipment with certain changes and adjustments, such, for example, as a wider spacing between the cylinder teeth and the concave teeth. It also appears desirable to use a special bean cylinder and concaves where large acreages are harvested.

The Pennsylvania Experiment Station reported that harvesting requires from 42 to 54 per cent of the total labor required in producing a potato crop in the State. Picking up the potatoes, which is now entirely a hand operation, requires from 25 to 33 per cent of the labor required in producing the crop. Engine-driven potato diggers were found to do better work than traction driven diggers and mechanical pickers were unsatisfactory under Pennsylvania conditions, due to the difficulty of securing soil and stone separation and the

heavy yields. It appears that lower forward speeds are necessary with high yields if mechanical potato pickers are to be used.

GRAIN CLEANING MACHINERY

The proper cleaning of grain is assuming considerable importance in the production of grain crops. The U. S. Department of Agriculture found during the year that part of the weed seeds in grain can be removed with present types of grain cleaners available for combines if the windrow method of harvesting is used.

The Reichskuratorium for Technical Agriculture of Germany has pointed out that grain-cleaning equipment should provide at the outset for dust removal. A wind-blast sorting device for separation of the grain kernels according to their specific weights is also a desirable feature. In addition, sieving apparatus for sorting according to size, and equipment for sorting according to the shape of the kernels are desirable. The results of experiments also suggest the advisability of means for treating the grain for protection against fungous diseases. It has been found that air blasts tend to separate grain kernels according to size, due primarily to the relatively greater surface friction of the small kernels.

CROP DRYING EQUIPMENT

The importance of maintaining superior quality in crops regardless of the conditions under which they were harvested has received considerable emphasis in recent work. The New York Cornell, Virginia, Indiana, and Illinois Experiment Stations especially have been active in this connection. At the Virginia Station experiments on grain drying by natural ventilation indicated the promise of simple, naturally ventilated bins for eastern farmers using the combine. An outstanding finding was the close relation between the moisture content of wheat and the relative humidity. It appears that rainfall does not affect the moisture content of standing wheat except as it causes a change in the relative humidity.

The Illinois Experiment Station, in continuing the corn-curing experiments, found that a drying temperature of 130° F. did not lower the germination percentage of corn, but a temperature between 140 and 150° F. materially decreased germination. However, there appears to be no objection to the use of a drying temperature as high as 150° F. for corn used in livestock feeding. The Indiana Station was able to dry out moist corn and make it fit for permanent storage at a cost of fuel of three cents per bushel.

The Division of Agricultural Engineering of the U. S. Department of Agriculture found that wheat could be reduced in moisture content from 18 to 14 per cent in from approximately 40 to 80 minutes, depending largely upon the rate at which heat was applied. The number of British thermal units supplied by the heater in drying the grain varied from 14,320 to 10,240 per bushel. The results also seemed to show that the quantity of air forced through the grain is significant only in so far as it affects the number of British thermal units supplied. It appears that the heat

requirements for drying wheat are equivalent to about 1 pound of coal per bushel of wheat at 100 per cent efficiency for the heating unit.

Rice drying studies by the California Experiment Station showed that bound rice placed in shocks lost most of its moisture during the first 80 hours after cutting, while bundles laid flat on the stubble dried out a similar amount in from 50 to 55 hours. Very little moisture loss occurred after these periods.

These typical undertakings recognize the requirements of the finished products as determined by agronomists, and are endeavoring to meet them satisfactorily with the aim of increasing the value of the resulting crop.

DAIRY EQUIPMENT

The proper development of different types of dairy equipment along lines of efficiency and economy is assuming considerable importance. During the year the California Experiment Station, for example, established the thermo-dynamic equations involved in the heating of milk cans over steam jets. The results of the tests indicated that wet or saturated steam is best for the first steaming but that this should be followed by a second heating with superheated steam for satisfactory results in a can washer. The superheated steam left less moisture to be removed than did wet or saturated steam. In the same connection the Reichskuratorium for Technical Agriculture of Germany obtained mechanical, bacteriological, and chemical results which, as a whole, indicate the superiority of mechanical cleaning over hand cleaning for the inside of milk cans, and the superiority of hand cleaning for the outside of the cans. It appears, however, that the internal cleaning by mechanical means is still far from perfect and considerable research is necessary to correct the defects of available methods and equipment.

The work at the California Station with a large size steam-type electrically heated dairy sterilizer showed that good bacterial reduction was possible and that the heating was sufficiently rapid for practical purposes. Prompt withdrawal of the equipment from the sterilizer was found to be desirable to avoid rusting. These typical studies indicate the necessity of coordinating the efforts of agricultural engineers with dairy bacteriologists and chemists in the solution of dairy equipment problems.

In addition, work was done at the California Station on the development of solar heaters to utilize solar energy for heating water for dairy and household purposes. Data taken in northern California on a bright sunshiny day between the hours of 8.00 a.m. and 5.00 p.m. showed an average absorption of 2.23 British thermal units per minute per square foot of exposed area by a single glass covered stationary absorber. It was possible to increase the efficiency of this type of absorber approximately 15 per cent by embedding the coil in cement plaster having a black painted surface exposed to the sunlight. The Alabama Experiment Station also developed a device which uses the energy of the sun for heating water consisting of three 30x60 inch sections built of corrugated roofing rivited

to flat roofing and so arranged that the water will pass between the two middle surfaces. The heater is covered with glass. The water temperature obtained in the months of August, September, and October ranged from 90 to 150° F., providing water in sufficient quantities for the use of a dairy of 30 cows.

MISCELLANEOUS MACHINERY

Considerable work was done during the year in the development of miscellaneous mechanical processes and equipment along cost-saving and profit-creating lines.

With reference to the grinding of feed, for example, the Indiana Experiment Station has found that grinding whole grain in the ration for dairy cows increases production 8.5 per cent but that excessively fine grinding does not pay. Similar results were obtained with reference to the grinding of grain for hogs. Grinding was found by the Idaho Experiment Station to be a profitable method of preparing alfalfa and other farm crops and by-products for cattle feeding. Ground alfalfa hay gave better results than short-cut or long hay as cattle feed, and waste was reduced. The results were not so good with feeding lambs, however, indicating the importance of close cooperation with the animal nutrition specialist in work of this character.

The Agricultural Academy of Berlin has done some work on the tractive resistance of farm wagons which is worthy of mention. The results with the two-wheel wagon on five different soil types indicated that tractive resistance depends mainly on the wheel dimensions on both light and heavy soils, the draft decreasing as the wheel diameter increases. Four-wheel wagons with the same loads and wheel dimensions showed a lower draft than did two-wheel wagons. A uniform distribution of the load over front and rear wheels of four-wheel wagons was also in favor of lower draft. The results also showed the value of roller bearing axles and dust proof hubs. It is significant that the work throughout was controlled by the conditions of practical farm hauling.

Work by the same institution on the power requirements of a mower indicated that as a whole the efficiency of a mower decreases with increasing speed. It appears that a relatively large proportion of the power required in the operation of a mower is expended in overcoming the inertia and friction of the machine itself. The frictional losses were found to increase almost with the cube of the speed. The favorable influence on power requirements of proper shaping of the sickle teeth, exact alignment of the crankwheel, the use of antifriction bearings, and proper balance of the crankshaft and pitman, was demonstrated. At a forward speed of about 8 feet per second the power required was normally about 7 horsepower. However, as the hay became more tough or tangled this requirement could easily be increased to 9 or 10 horsepower and the efficiency of the mower decreased accordingly. The necessity for a thorough consideration of the requirements of the crop to be cut is thus clearly demonstrated.

CONCLUSION

The above brief review of typical outstanding results of mechanical farm equipment studies during the year points to the importance of clarifying and defining a field of research. That process, as applied to mechanical farm equipment, has revealed the existence of a large number of important mechanical problems in programs of agricultural research, the most of which materially affect the economy and efficiency of some line of agricultural production. In most instances noted above the need for engineering investigation arises from some very definite agricultural problem. Such participation may require the testing or comparing of available equipment, or the development of new equipment on the basis of known standards or established requirements. It may even call for original research to establish the fundamental principles involved in a practice, such as tillage or traction, for example, to provide a basis for the rational development of the necessary equipment. In practically every instance, however, the proper line of attack calls for the coordination of the efforts of agricultural engineers with those of agronomists, soil technologists and other subject-matter specialists, in the study of specific mechanical problems.